Technical Note

Carbon Footprint of TOC Removal Technologies

Comparison of the MIEX® Process, GAC, Ozone & High Pressure Membranes

V0509

Introduction

The accelerating impact that climate change is having on our local weather patterns and water resources is increasing awareness of the human contributions to global warming. For the water industry, more severe weather events and less reliable rainfall patterns will have a major impact on drinking water sources in terms of quantity and quality. Advanced water treatment technologies will be required as the quality of existing water sources deteriorates and new sources of poorer quality are required to make-up for dwindling existing supplies. These technologies are generally more energy intensive than conventional treatment processes[1] which can significantly increase a treatment plant's carbon footprint and further expose a utility to increasing energy costs.

A major water treatment challenge encountered in the search for new water sources is the removal of total organic carbon (TOC) to reduce disinfection by-product formation, color and membrane fouling. Granular activated carbon (GAC) adsorbers, ozone followed by GAC, high-pressure membranes and the MIEX® ion exchange process are technologies being considered to provide advanced levels of TOC removal. This technical note compares the sustainability of these TOC removal technologies in terms of carbon footprint.

Carbon Footprint of TOC Removal Processes

The carbon footprint (CF) of a water treatment process is typically defined as the sum of green house gases (GHGs) produced, expressed as carbon dioxide equivalents, from operational and embodied emissions[2]. Operational emissions are direct emissions of GHGs from the use of a natural resource in the treatment process such as electricity and natural gas. Embodied emissions are GHG emissions that were generated in the manufacture of equipment or a chemical prior to its intended use. A summary of the GHG emissions produced in the ongoing operation of TOC removal technologies is shown in Table 1. The CF of the initially installed equipment has not been included in this comparison as this contribution to GHGs is insignificant over the life of the treatment plant compared to the emissions generated from operation of these processes. Detailed assumptions for estimating the carbon footprint are outlined in the following section.

Table 1: Summary of GHG Emissions from Operation of Various TOC Removal Technologies

Technology	Ongoing Emissions	
	lb CO_2/MG	kg CO_2/ML
GAC Adsorbers	**3535**	**424**
Nanofiltration	**3432**	**411**
Ozone	**449**	**54**
MIEX® Process	**66**	**8**

Table 1 shows that **the carbon footprint of operating GAC adsorbers and nanofiltration membranes is over fifty times that of the MIEX® Process**. A continuous ozone dose of 5mg/L produces nearly seven times the GHG emmissions of the MIEX® Process.

Carbon Footprint Calculations

The carbon footprint for the ongoing operation of TOC removal processes has been calculated using the following general assumptions:

1. CO_2 released[3] per kWh: 0.6 kg/kWh (1.3 lb/kWh)

2. GHG emissions from the following have **not** been included:

- Transportation of chemicals to site (GAC, MIEX® Resin, NaCl)

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- NF Membrane replacement and membrane cleaning chemical manufacture
- Spent GAC disposal and MIEX® Resin regeneration waste disposal
- Impacts on other treatment processes

Specific assumptions are:

Granular Activated Carbon Adsorption (GAC)	
Variable	**Value**
GAC Replacement Frequency	180 days
Empty Bed Contact Time	20 minutes
GAC Consumption	322 lb/MG (39 kg/ML)
GHG Emissions from GAC Manufacture[4]	11 lb CO_2 per 1 lb GAC produced
Carbon Footprint	**3535 lb CO_2 released per MG of water treated**

Nanofiltration Membranes	
Variable	**Value**
Power Consumption to Operate	2500 kWh/MG (660 kWh/ML)
Carbon Footprint	**3432 lb CO_2 released per MG of water treated**

Ozone	
Variable	**Value**
Ozone Dose	5 mg/L
Power Consumption from Ozone Manufacture	8.2 kWh per 1lb Ozone produced (18 kWh/kg Ozone)
Carbon Footprint	**449 lb CO_2 released per MG of water treated**

MIEX® Process	
Variable	**Value**
GHG Emissions from MIEX® Resin Replacement	37.6 lb CO_2/MG (4.5 kg CO_2/ML)
Salt Consumption	300 lb/MG (36 kg/ML)
GHG from NaCl Production	0.20 lb CO_2 per 1 lb NaCl
Power Consumption to Operate	38 kWh/MG (10 kWh/ML)
Carbon Footprint	**66 lb CO_2 released per MG of water treated**

Note: The MIEX® Process can also provide reductions in the carbon footprint of downstream treatment processes through reductions in coagulant demand, pH adjustment chemicals, sludge volumes and chlorine demand. ***In some cases the installation of the MIEX® Process has been carbon-neutral or even provided a carbon sink due to the downstream reductions in GHG emissions.***

Conclusions

While treatment processes such as GAC and high-pressure membranes can produce water of excellent quality, these processes are very energy intensive and subsequently have large carbon footprints. The carbon footprints of GAC and Nanofiltration were determined to be over fifty times that of the MIEX® Process. Even an ozone dose of 5 mg/L produces nearly seven times the GHG emissions of the MIEX® Process.

The MIEX® Process has a very low energy intesity and therefore a small carbon footprint. In addition, as the MIEX® Process is a pre-treatment step, it can provide reductions in GHG emissions from downstream processes that can make installing the process carbon-neutral. These reductions will not be provided by polishing processes such as GAC and Nanofiltration. The MIEX® Process therefore has a significantly smaller carbon footprint compared to the other advanced TOC removal technologies and when downstream reductions are taken into consideration, may even provide a net carbon sink across all treatment processes.

References

1. Reiling, S; Roberson, A; Cromwell III, J; "Drinking Water Regulations: Estimated Cumulative Energy Use and Costs," Journal AWWA March 2009.
2. Strut, J; Wilson, S; Shorney-Darby, H; Shaw, A, Byers, A; "Assessing the carbon footprint of water production," Journal AWWA, June 2008.
3. U.S. Average, USEPA, 2004
4. Bayer, P; Heuer, E; Karl, U; Finkel, M; "Economical and ecological comparison of granular activated carbon (GAC) adsorber refill strategies," Water Research, March 2005.

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